# AERMOD Ethylene Oxide Emergency Release Air Dispersion Modeling for Becton Dickenson Sandy Utah Facility

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## Executive Summary

Becton Dickenson (BD) has expressed an interest in quantifying the ambient concentrations of Ethylene Oxide (EO) as a result of possible accidental releases of the compound from their Sandy, Utah, sterilization facility. A number of different locations were identified as possible areas where an emergency release could occur and these include:

- Scenario 1: Release from the chamber room;
- Scenario 2: Release from the pressure relief valves on the penthouse roof;
- Scenario 3: Release from the gas storage area;
- Scenario 4: Release from the gas dispensing area, and;
- Scenario 5: Release of aqueous EO solution in the Lesni Pad area.
- Scenario 6: Hypothetical simultaneous release of all sources lists above (for information purposes only to help establish upper limit on plant-wide impacts).

The US EPA air dispersion model AERMOD was used to quantify the impacts of emergency releases from these locations. Three years of local meteorological data were used to determine the worst-case impacts on the surrounding area. Three EO health-related criteria were used for comparison with the modeled results:

- 800 ppm over maximum 1-minute release (OSHA Immediate Danger to Life and Health (IDHL))
- 5 ppm over maximum 15-minute release (ACGIH Short-term Exposure Limit (STEL))
- 1 ppm over maximum 8-hour release (OSHA Permissible Exposure Limit (PEL))

The results indicate that the highest off-property impacts occur near the property line during the over-night hours when there are stable atmospheric conditions. The results are summarized below in Exhibit 1.

EXHIBIT 1
Ethylene Oxide Dispersion Modelling Summary – All Receptors

| | Criteria (ppm) | Scenario 1 (ppm) | Scenario 2 (ppm) | Scenario 3 (ppm) | Scenario 4 (ppm) | Scenario 5 (ppm) | Scenario 6 (ppm)† |
|---|---|---|---|---|---|---|---|
| 1-minute | 800 | 32.5 | 233.1 | 41.2 | 34.1 | 36.9 | 260.3 |
| 15-minute | 5 | 32.5 | 31.1 | 41.2 | 34.1 | 36.9 | 104.3 |
| 8-hour | 1 | 0.70 | 0.66 | 1.7 | 1.7 | 4.1 | 6.9 |

†All sources emitting simultaneously

No exceedences were predicted for the short-term OSHA criterion of 800 ppm for any of the scenarios.

Exceedences were predicted for the 15-minute averaging ACGIH criterion of 5 ppm. Typical maximum on-site concentrations were 30-40 ppm for all scenarios 1 through 5. Considering only off-site impacts, the maximum concentrations were approximately 5-10 ppm for scenarios 1 through 4 while no exceedences were predicted for scenario 5. The model predicted that the maximum distance from the sources where concentrations are expected to be above 5 ppm was approximately 400- 500 m for scenarios 1 through 4, or approximately 100-200 m off the property line.

Localized on-site exceedences of the 8-hour PEL criterion (1 ppm) were predicted by the model for scenarios 3 through 5 but no off-property exceedences.

## Background

Becton Dickenson (BD) has expressed an interest in quantifying the ambient concentrations of Ethylene Oxide (EO) as a result of possible accidental releases of the compound from their Sandy, Utah, sterilization facility. In particular, there are a number of residential areas in close proximity to the facility that are a concern.

A number of different source release rates, control fan speeds, temperature dependence, and atmospheric conditions have been identified as factors that Becton Dickenson wishes to have assessed during the accidental release scenario modeling. It was determined that since the facility is in an area with several buildings and the emergency exhaust controls will provide buoyancy and EO dilution to the emitted plume, AERMOD would be best suited to accurately evaluate the large number of parameters that could affect the dispersion of the accidental EO plume. AERMOD is also able to handle both point source and fugitive (volume) source emissions. It is understood that this assessment and report are confidential and intended for Becton Dickenson internal use only.

Exhibit 2 shows the area surrounding the facility and property-line.

EXHIBIT 2
Layout of Area Surrounding the Becton Dickenson Sandy Utah Facility


## Dispersion Modeling Methodology

The dispersion modeling analysis for this project was conducted using the latest version of the **A**MS/**E**PA **R**egulatory **Mod**el (AERMOD – Version 07026) to estimate maximum ground-level concentrations. AERMOD is a steady-state plume model that incorporates planetary boundary layer (PBL) theory to define ambient turbulence parameters. AERMOD is the recommended model for use in regulatory industrial source modeling as defined in the Guideline on Air Quality Modeling (40 CFR 51, Appendix W) and the Ohio EPA Engineering Guide #69: Air Dispersion Modeling Guidance.

The analysis includes an evaluation of the possible effects of elevated terrain, and aerodynamic effects (downwash) due to nearby building(s) and structures on plume dispersion and ground-level concentrations. The model combines simple and complex terrain algorithms, and includes the Plume Rise Model Enhancement (PRIME) algorithms to account for building downwash and cavity zone impacts.

The required emission source data inputs to AERMOD include source location, source elevation, stack height, stack diameter, stack exit temperature, stack exit velocity, and pollutant emission rates. The source locations are specified for a Cartesian (x, y) coordinate system where x and y are distances east and north in meters, respectively. The Cartesian coordinate system used for these analyses is the Universal Transverse Mercator Projection (UTM), North American Datum (NAD83).

The AERMOD model was used with regulatory default options as recommended in the EPA Guideline on Air Quality Models as listed below:

- Accept terrain elevations and hill height input
- Use stack-tip downwash
- Perform meteorological data checking

The complete AERMOD modeling system is comprised of three parts: the AERMET pre-processor, the AERMAP pre-processor, and the AERMOD model. The AERMET pre-processor compiles the surface and upper-air meteorological data and formats the data for AERMOD input. The AERMAP pre-processor is used to obtain elevation and controlling hill heights for AERMOD input.

## Release Scenarios and Emission Estimates

The ethylene oxide criteria used for comparison are the 15-minute ACGIH short-term exposure limit (STEL) of 5 ppm (9015 μg/m$^3$), the OSHA permissible exposure level (PEL) of 1 ppm EO (1,803 μg/m$^3$) for 8-hour averages, and the short-term (1-minute average) OSHA where there is immediate to life and health, 800 ppm (1.44 g/m$^3$ of ethylene oxide). These criteria are summarized below in Exhibit 3.

EXHIBIT 3
Health Criteria for Ethylene Oxide

| Ethylene Oxide Level in ppm | Averaging Period | Resulting Conditions on humans |
|---|---|---|
| 1 | 8-hr | OSHA Permissible Exposure Limit (PEL) |
| 5 | 15-minute | ACGIH Short-term Exposure Limit (STEL) |
| 800 | 1-minute (maximum possible emission rate) | OSHA Immediate Danger to Life and Health (IDHL) |

Preliminary discussions with Becton Dickenson identified a larger number of possible emissions scenarios that varied over source release rate, fan exhaust rates, ambient temperatures, wind speeds and atmospheric stability classifications. From those possible emissions scenario, only a few were run, which constituted the worst-case impacts from each of the possible source locations. The variations that could occur in wind speed and stabilities are implicitly accounted for by using three years of meteorological data, which would contain all possible combinations of these parameters leading to worst-case predictions.

### Scenario 1

Scenario 1 involves the release of 120 lbs of EO from the chamber room. The chamber room has a normal exhaust of 6150 cfm, which increases to 12,300 cfm when EO concentrations within the room reach 5% LEL. The maximum release rate from the two exhaust fans serving the chamber room occur when 8 lbs/minute are being emitted, or 120 lbs over a 15-minute period. The maximum release over an 8-hour period would remain 120 lbs or 15 lbs/hr averaged over 8 hours. The exhaust fans for this and subsequent scenarios assume that the fans have been tripped to “purge” or emergency flow rates, double the normal flow (where such controls exist).

### Scenario 2

Scenario 2 involves the release of 40 lbs of EO from the roof of the penthouse. The discharge would be as a result of failure of the pressure relief valve during a positive pressure cycle. It is estimated that 40 lbs of EO would be lost during the scenario and the release would occur through two 3 inch pipes with rain caps originating from the chamber terminating at 45 feet above grade. The maximum release rate from the relief valves would be 20 lbs over a one-minute period or the entire available 40 lbs over a 15-minute period. The maximum release over an 8-hour period would remain 120 lbs or 15 lbs/hr averaged over 8 hours.

Each of the six identified sources was a point source. Locations of each source are shown in Exhibit 5.

Since the release valves have a rain cap installed on the top, the flue gas exit velocity and stack diameter were adjusted to account for reduced escape velocity. The escape velocity was reduced to 0.1 m/s while flow volume remained constant, giving an effective diameter of 1.75 m.

### Scenario 3

Scenario 3 involves the release of 400 lbs of EO gas from a drum in storage. The initial drum pressure as a result of the release would drop from 45 to 7 psig. Two exhaust fans serve the gas storage area and activate to a higher flow rate (9000 cfm) when concentrations with the storage area reaches 3% LEL, with deluge at 25% LEL. The anticipated maximum rate of release from the drum would be 8 lbs/minute, 120 lbs/15 minutes, and the entire 400 lbs over an 8-hour period.

### Scenario 4

Scenario 4 involves the release of 400 lbs of EO gas from a drum in the gas dispensing area, just to the north of the storage area. Two exhaust fans serve the gas dispensing area and activate to a higher flow rate (20,200 cfm) when concentrations when the dispensing area reaches 3% LEL, with deluge at 25% LEL. Similar to Scenario 3, the anticipated maximum rate of release from the drum would be 8 lbs/minute, 120 lbs/15 minutes, and the entire 400 lbs over an 8-hour period.

### Scenario 5

Scenario 5 involves a scenario where there is a release of an aqueous solution of between 1 to 3% ethylene oxide by volume. This release would occur on the Lesni pad as shown in Exhibit 4. The worst-case EO emissions from Scenario 5 would be from the release of 100 gallons of 3% EO dissolved in water. Since ethylene oxide is very soluble in water, the amount of gaseous EO available for dispersion was taken to be similar to the amount of water vapor above the liquid water medium at a temperature of 25 °C. This would provide a conservative yet reasonable estimate of available EO from the aqueous solution.

## Scenario 6

A final scenario was considered that had all of the sources listed above emitting EO simultaneously. It is understood that this scenario is very highly unlikely and is presented in this report for information purposes only to help establish an upper limit of possible (though highly improbable) impacts.

A summary of modeled scenarios and emission quantities are shown below in Exhibit 4. Also, Exhibit 5 shows the approximate locations of the emission points and a source summary table is presented in Exhibit 6.

EXHIBIT 4
Summary of Emergency Release Scenarios for Ethylene Oxide

| Scenario | Description | Release Rate at Source | Controls | Maximum 1-minute EO release† | Maximum 15-minute EO release | Maximum 8-hour EO release |
|---|---|---|---|---|---|---|
| 1 | Release of 120 lbs of EO from chamber room | 1, 2, 4, 8 lbs/minute | Exhaust fan activates to high speed at 3% LEL | 8 lbs | 120 lbs | 120 lbs |
| 2 | Release of 40 lbs of EO from chamber pressure relief valve during positive pressure cycle | 5, 10, 20 lbs/minute | None | 20 lbs | 40 lbs | 40 lbs |
| 3 | Release of 400 lbs of EO gas from drum in storage, drum pressure will drop from 45 psig to 7 psig | 1, 2, 4, 8 lbs/minute | Exhaust fan activates to high speed at 3% LEL, deluge at 25% LEL | 8 lbs | 120 lbs | 400 lbs |
| 4 | Release of 400 lbs of EO gas from drum in storage | 1, 2, 4, 8 lbs/minute | Exhaust fan activates to high speed at 3% LEL, deluge at 25% LEL | 8 lbs | 120 lbs | 400 lbs |
| 5 | Release of 100, 500, 1000, and 10000 gallons of water containing 1%, 2%, and 3% EO by volume | 10, 50, 100 gallons per minute | outside in alley | 0.69 lbs[1] | 10.3 lbs[2] | 68.4 lbs[3] |

[1]Release at 100 gpm, 3% EO, for 1 minutes, density liquid EO is 7.36 lbs/gal, 3.1% vapor release from aqueous solution @ 25° C

[2]Release at 100 gpm, 3% EO, for 15 minutes, 3.1% vapor release from aqueous solution @ 25° C

[3]10,000 gallons of release at 3% EO, over 8 hours, 3.1% vapor release from aqueous solution @ 25° C

† Compare to OSHA IDHL criterion (800 ppm)

EXHIBIT 5
Release Locations for Modeled Scenarios

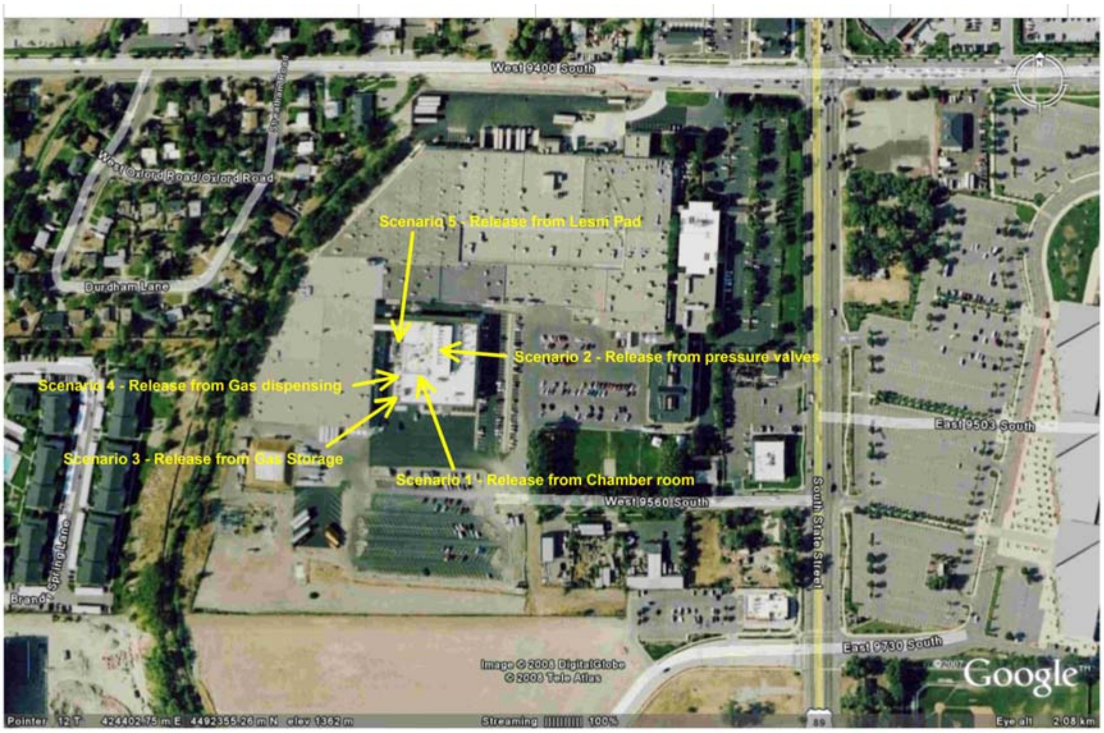


EXHIBIT 6
Source Summary Table of Emergency Ethylene Oxide Release Scenarios

| Contaminant | CAS # | Source Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Source ID | Source Type | Source Description | Stack Volumetric Flow Rate (cfm) | Stack Exit Gas Velocity (m/s) | Stack Exit Gas Temperature (°C) | Stack Inner Diameter (m) | Stack Height Above Grade (m) | Stack Height Above Roof (m) | Source Coordinates (x,y) (m) |
| Ethylene Oxide | 75-21-8 | SC1A | Point Source | Chamber room exhaust fan A | 6,500 | 14.22 | Ambient | 0.51 | 11.84 | 3 | 424297956, 4492362.668 |
| | | SC1B | Point Source | Chamber room exhaust fan B | 6,500 | 14.22 | Ambient | 0.51 | 11.84 | 3 | 424300.115, 4492362.421 |
| | | SC2 | Point Source | Relief Valves | 240 $dm^3/s$ | 0.1† | Ambient | 1.75† | 13.72 | 0.6 | 424319.529, 4492377.93 |
| | | SC3A | Point Source | Gas Storage Exhaust fan A | 4,500 | 14.22 | Ambient | 0.44 | 7.85 | 3 | 424282.496, 4492336.099 |
| | | SC3B | Point Source | Gas Storage Exhaust fan B | 4,500 | 14.22 | Ambient | 0.44 | 7.85 | 3 | 424283.437, 4492336.065 |
| | | SC4A | Point Source | Gas Dispensing exhaust fan A | 10,100 | 14.22 | Ambient | 0.44 | 7.85 | 3 | 424284.272, 4492351.304 |
| | | SC4B | Point Source | Gas Dispensing exhaust fan B | 10,100 | 14.22 | Ambient | 0.44 | 7.85 | 3 | 424285.298, 4492351.232 |
| | | SC5 | Volume Source | Lesni Pad Aqueous Solution Release | na | na | Ambient | na | Ground Level | Ground Level | 424283.152, 4492381.711 |
| Total | | | | | | | | | | | |

NA – not applicable

† Rain cap will reduce exit velocity, mass balance preserved by determining effective stack diameter

## Meteorology

Surface meteorological data for the years 2004 through 2006 inclusive were obtained for Salt Lake City International airport (WBAN #24127) from the National Climatic Data Center (NCDC). Upper air data was also from the Salt Lake City site for the same time period. A summary of the stations used in the meteorological dataset is shown in Exhibit 7. The surrounding land use for the AERMET meteorological pre-processing was assumed to be urban. The windrose for the Salt Lake City surface data is shown in Attachment A.

EXHIBIT 7
Summary of Meteorological Data Used in Analysis

| Station | WBAN ID | Latitude | Longitude | Height above MSL (m) | Anemometer Height | State | Comments |
|---|---|---|---|---|---|---|---|
| Salt Lake City | 24127 | 40.778N | 111.969W | 1288 | 20 ft | UTAH | Surface and Upper Air |

The area surrounding the meteorological station is generally urban/suburban on all sides, which is similar to the area surrounding the BD Sandy facility. Also, the BD site is in close proximity to the Salt Lake City airport, approximately 23 km south southeast of the airport. Therefore, the meteorological data is thought to be representative of the BD facility.

Seasonal variations in albedo, surface roughness, and Bowen ratio consistent with the urban land use classification were included in the AERMET processing. *EXHIBIT 8* below lists the seasonal AERMET land-use parameters used in the input files. A surface roughness of 0.70 was used consistent with a small city and/or suburban area. The AERMET user's manual was used to select parameters consistent with the the land use for the surrounding area.

EXHIBIT 8
Seasonal AERMET Surface Parameters for Salt Lake City Airport Meteorological Station

| Land Use | Albedo | | | | Bowen Ratio (average moisture) | | | | Surface Roughness | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Season | | | | Season | | | | Season | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Urban | 0.35 | 0.14 | 0.16 | 0.18 | 1.5 | 1.0 | 2.0 | 2.0 | 0.70 | 0.70 | 0.70 | 0.70 |

1 – Winter (DJF)

2 – Spring (MAM)

3 – Summer (JJA)

4 – Fall (SON)

## Receptor Grid

The base modeling receptor grid for AERMOD modeling consisted of 13,281 receptors that were placed at spacing that increases with distance from the origin. All on-site and off-site receptors were used in the analysis. The receptor heights were assumed to be ground-level.

A 2 km by 2 km grid centered on the site was sufficient to capture the contaminant maxima as well as have the estimated concentrations near the grid border be less than the criterion used for assessment (c.f. Exhibit 2). A multi-tiered receptor grid was selected with spacing as follows:

- 5 m spacing out to a distance of 150m from the vicinity of the gas storage area (origin 424300 UTM NAD83 Easting, 4492370 UTM NAD83 Northing).
- 10 m spacing was used within 500 meters from the origin;
- 100 m spacing was used to 1000 m from the origin.

## Terrain

Terrain in the vicinity of the project was accounted for by assigning base elevations to each receptor. Data at 7.5-minute intervals (10- by 10-meter spacing) from the U.S. Geological Survey (USGS) Digital Elevation Model (DEM) were used in conjunction with the AERMAP pre-processor (version 06341) to determine receptor elevations. The NAD83 Universal Transverse Mercator (UTM) Zone 12 coordinate datum was used for all the modeling.

On-site source and building elevations were determined from preliminary design maps and other survey data, not from the DEM data. Elevations of all receptors were derived from DEM maps.

## Building Downwash Effects

Buildings or other solid structures may affect the flow of air in the vicinity of a source and cause building downwash (*e.g.*, eddies on the downwind side) which have potential to reduce plume rise and increase dispersion.

For dispersion modeling purposes, building downwash effects were considered for sources at the BD Sandy facility. Exhibit 9 shows the locations of the buildings used in the assessment and Exhibit 10 lists the important buildings and structures located at the site and their respective heights.

EXHIBIT 9
Buildings Included in Air Dispersion Modeling

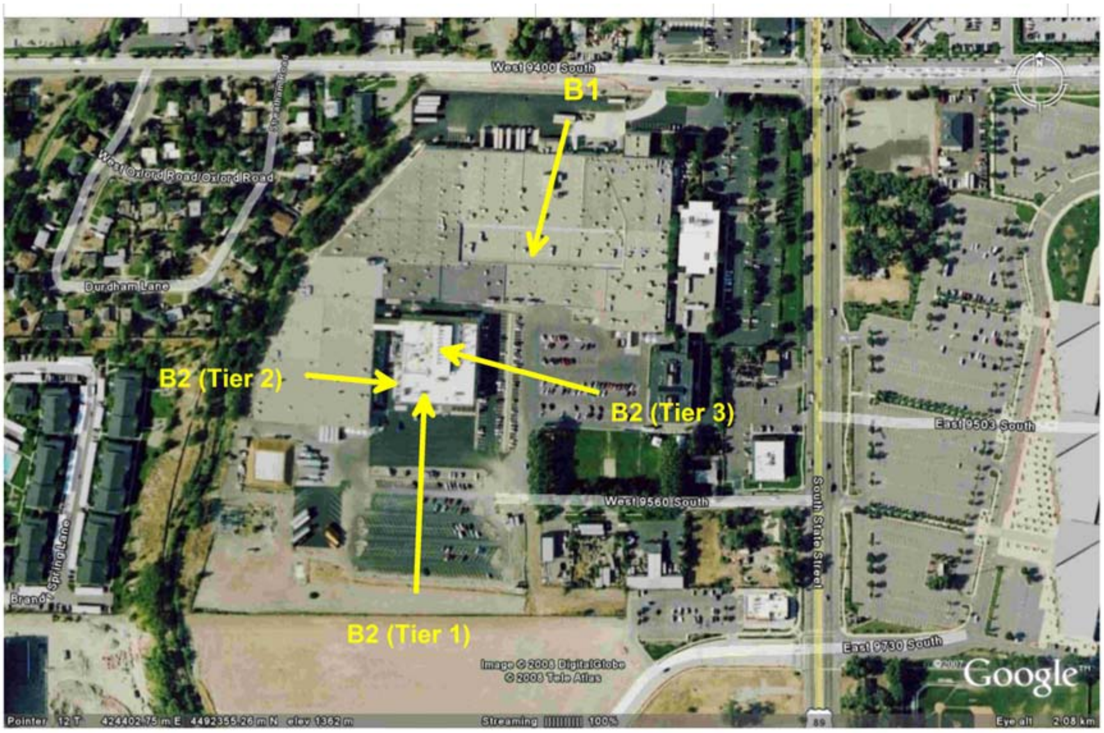



EXHIBIT 10
Heights of Important Buildings and Structures at the BD Sandy Plant.

| Building Name | Building ID | Height (m) |
|---|---|---|
| Main Building | B1 | 7.3 |
| ETO structure – warehouse | B2 – Tier 1 | 8.8 |
| ETO Structure – Gas storage and dispensing | B2 – Tier 2 | 4.8 |
| ETO Structure – Penthouse | B2 – Tier 3 | 13.1 |

## Ambient Background Ethylene Oxide Concentrations

There are a few ambient measurements of ethylene oxide in the United States. Some limited additional data were identified for the urban area of Los Angeles, California (Havlicek *et al.* 1992). The ambient air concentrations from Los Angeles are likely to be higher than would be expected to occur in the Sandy, Utah, area. Los Angeles is located in a geographic area (i.e., a basin) that can cause reduced air movement and contribute to higher pollutant levels in the air. The maximum mean 24-hour ambient air concentration detected in the Los Angeles urban area was found to be 956 $\mu g/m^3$ (0.53 ppm). This ambient concentration is a significant fraction of the OSHA permissible exposure level. However, since the applicability of this concentration to local levels is most likely subject to significant error, background levels were not included in the overall analysis, and not included in the concentration contour plots in Attachment B.

### Dispersion Modeling Methodology

The air dispersion modeling scenarios were run using the entire 3-years of meteorological data discussed above. A data set of this duration should ensure that worst-case combinations of wind speed and atmospheric conditions should occur, and therefore worst-case predictions for ambient EO concentrations. The facility is designed to operate 24 hours a day and 7 days a week, and therefore all hours of the day were modeled.

For each of the scenarios, maximum ground-level concentrations were calculated using the AERMOD air dispersion model. The resulting concentration contours are presented in Attachment B and represent the worst-case concentrations for each receptor over the course of the three-year simulation period.

The AERMOD model produces only one-hour or longer averaging period predictions and therefore all shorter-average emission rates were scaled accordingly such that the correct short-term average concentration predictions were made; for instance, 15-minute averaging period emissions were multiplied by 4 to correspond to the emissions that would occur over a one-hour period.

The molecular weight of ethylene oxide gas is 44.05 and as such is denser than (dry) air that has an average molecular weight of approximately 29 g/mol. However, prior to the release of relatively small amounts of ethylene oxide from the various sources, a significant amount of mixing of the EO is expected to take place with the ambient air, and as such the initial air parcel is expected to be neutrally buoyant and relatively dilute in concentration, similar to the component of $CO_2$ in ambient air. Therefore, the use of AERMOD was deemed appropriate for this analysis. Further, AERMOD is a relatively sophisticated model that is able to use real meteorology and incorporate a number of site specific factors into the dispersion analysis, which would lead to more refined and accurate estimates of EO ambient concentrations.

Ethylene oxide has a boiling point of 10.7 °C. It is therefore possible that as ambient temperatures fall below this point, there may be some condensation of gaseous EO and subsequent deposition. For the purposes of the modeling, it is assumed that the initial plume is released at ambient temperature and contains relatively dilute concentrations of EO due to some pre-mixing with ambient air. As such, condensation may be slow and deposition was not explicitly included in the analysis. As a result, the predicted results may be somewhat conservative for low temperature conditions.

# 3 Discussion of Results

Plume dispersion calculations were performed to assess the impact of possible EO emissions at the BD Sandy facility on ambient air quality within the study area. The modeling results are presented within the following sections.

The results of the ethylene oxide dispersion modeling are presented below in Exhibit 11 for all on- and off-property receptors and the concentration contour plots are shown in Attachment B. If there were exceedences of the applicable criteria, the contours are shown in each of the plots to show the aerial extent of the exceedences. However, it should be noted that concentration contour plots are shown regardless of whether or not the particular scenario predicted an exceedance.

Exhibit 12 lists the results considering only off-property receptors, which includes the facility fenceline and all receptors further afield. Exhibit 13 summarizes the aerial extent of the exceedences in squared kilometers.

EXHIBIT 11
Ethylene oxide Dispersion Modeling Summary – All Receptors

| | Criteria (ppm) | Scenario 1 (ppm) | Scenario 2 (ppm) | Scenario 3 (ppm) | Scenario 4 (ppm) | Scenario 5 (ppm) | Scenario 6 (ppm)† |
|---|---|---|---|---|---|---|---|
| 1-minute | 800 | 32.5 | 233.1 | 41.2 | 34.1 | 36.9 | 260.3 |
| 15-minute | 5 | **32.5** | **31.1** | **41.2** | **34.1** | **36.9** | **104.3** |
| 8-hour | 1 | 0.70 | 0.66 | **1.7** | **1.7** | **4.1** | **6.9** |

†All sources emitting simultaneously

EXHIBIT 12
Ethylene oxide Dispersion Modeling Summary – Off-property Receptors Only

| | Criteria (ppm) | Scenario 1 (ppm) | Scenario 2 (ppm) | Scenario 3 (ppm) | Scenario 4 (ppm) | Scenario 5 (ppm) | Scenario 6 (ppm)† |
|---|---|---|---|---|---|---|---|
| 15-minute | 5 | **8.5** | **5.7** | **10.5** | **8.5** | 1.5 | **27.1** |
| 8-hour | 1 | 0.13 | 0.07 | 0.48 | 0.47 | 0.14 | **1.2** |

†All sources emitting simultaneously

EXHIBIT 13
Land Surface area of Ethylene oxide Exceeding Criteria including BD Property– All Receptors (squared kilometers)

| | Criteria (ppm) | Scenario 1 (ppm) | Scenario 2 (ppm) | Scenario 3 (ppm) | Scenario 4 (ppm) | Scenario 5 (ppm) | Scenario 6 (ppm)† |
|---|---|---|---|---|---|---|---|
| 1-minute | 800 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15-minute | 5 | 0.23 | 0.086 | 0.34 | 0.32 | 0.008 | 1.48 |
| 8-hour | 1 | 0 | 0 | 0.008 | 0.009 | 0.002 | 0.046 |

†All sources emitting simultaneously

A discussion of the impacts of each of the scenarios follows.

## Scenario 1 - Release of EO from Chamber Room

Scenario 1 involves the accidental release of EO gas from the chamber room. The maximum predicted concentration at all receptors over a 1-minute and 15-minute release period was 32.5 ppm, which is less than the IDHL criterion of 800 ppm but greater than the STEL criterion of 5 ppm for the 15-minute averaging period. The maximum overall concentrations occurred under stable overnight atmospheric conditions with light wind speeds for both the "all receptor" run and the off-property run. The maximum off-property concentration occurs at the southeast portion of the property line. The maximum distance from the source where a concentration of greater than 5 ppm is found is east approximately 430 m from the source, and 100 m east of State Street. No exceedence of the 8-hr criterion of 1 ppm was predicted.

### Scenario 2 - Release of EO due to Failed Pressure Relief Valves

Scenario 2 involves the accidental release of EO gas from the roof area of the penthouse from a malfunction of the pressure relief valves during a positive pressure cycle. The maximum predicted concentration at all receptors over a 1-minute period was 233.1 ppm and 31.1 over a 15-minute release period. Similar to scenario 1, the predicted concentration is less than the IDHL criterion of 800 ppm but greater than the STEL criterion of 5 ppm for the 15-minute averaging period. The maximum off-property concentration occurred under stable overnight atmospheric conditions with light wind speeds and was located on the southeast fenceline. A few exceedences also occurred on the northwest fenceline but none occurred further away from the source. The maximum distance from the source where a concentration of greater than 5 ppm is found is to the southeast approximately 150 m from the source. No exceedences of the 8-hr criterion of 1 ppm were predicted.

### Scenario 3 – Release of EO from Gas Storage Area

Scenario 3 involves the accidental release of EO gas from the gas storage area. The maximum predicted concentration at all receptors over a 1-minute and 15-minute release period was 41.2 ppm, which is less than the IDHL criterion of 800 ppm but greater than the STEL criterion of 5 ppm for the 15-minute averaging period. The maximum overall concentrations occurred under stable overnight atmospheric conditions with light wind speeds for both the "all receptor" run and the off-property run. The maximum distance from the source where a concentration of greater than 5 ppm over a 15-minute averaging period is found is east-northeast approximately 480 m. Exceedences are also predicted to occur 250 m to the northwest and 420 m to the north. The maximum off-property concentration occurs on the northwest fenceline.

No exceedance of the 8-hr criterion of 1 ppm was predicted for the off-property run but localized on-site areas of exceedance immediately to the north and east of the emissions point were predicted.

### Scenario 4 – Release of EO from Gas Dispensing Area

Scenario 4 involves the accidental release of EO gas from the gas dispensing area. The maximum predicted concentration at all receptors over a 1-minute and 15-minute release period was 34.1 ppm, which is less than the IDHL criterion of 800 ppm but greater than the STEL criterion of 5 ppm for the 15-minute averaging period. The maximum overall concentrations occurred under stable overnight/early morning atmospheric conditions with light wind speeds for both the "all receptor" run and the off-property run. The maximum distance from the source where a concentration of greater than 5 ppm over a 15-minute averaging period is found is north approximately 480 m. In general, exceedences are predicted to occur approximately 100-200 m off the property line in all directions except to the south east. The maximum off-property concentration occurs on the northwest fenceline.

No exceedance of the 8-hr criterion of 1 ppm was predicted for the off-property run but localized on-site areas of exceedance immediately to the north, south and east of the emissions point were predicted.

### Scenario 5 – Release of Water Containing Dissolved Ethylene Oxide

Scenario 5 involves the accidental release of an aqueous solution of EO from the Lesni Pad area, just to the north of the gas dispensing area. Due to the low-lying nature of the release, there is a small area of exceedences for the worst-case emission where 100 gallons per minute of 3% by volume EO is release. However, the area is highly localized and no off-property exceedences are predicted, even for the conservative estimate used in the assessment. Also, no exceedance of the 8-hr criterion of 1 ppm was predicted.

### Scenario 6 – Simultaneous Release of all Sources

Scenario 6 is the hypothetical situation where all sources are emitting simultaneous and at their maximum rate of release. As mentioned above, scenario 6 is extremely unlikely and is provided for information only. The results of this hypothetical scenario are provided in Exhibits 11 through 13 above.

# 4 Summary of Results

The results indicate that the highest off-property impacts occur near the property line during the over-night hours when there are stable atmospheric conditions.

No exceedences were predicted for the short-term OSHA criterion of 800 ppm for any of the scenarios.

Exceedences were predicted for the 15-minute averaging ACGIH criterion of 5 ppm. Typical maximum on-site concentrations were 30-40 ppm for all scenarios 1 through 5. Considering only off-site impacts, the maximum concentrations were approximately 5-10 ppm for scenarios 1 through 4 while no exceedences were predicted for scenario 5. The model predicted that the maximum distance from the sources where concentrations are expected to be above 5 ppm was approximately 400- 500 m for scenarios 1 through 4, or about 100-200 m off the property line. The maximum distance of elevated impact from the property line was dependent on the release characteristics of the individual scenarios.

Localized on-site exceedences of the 8-hour PEL criterion (1 ppm) were predicted by the model for scenarios 3 through 5 but no off-property exceedences.

# 5 Closure

This report has been prepared on behalf of and for the exclusive use of Becton Dickenson and its representatives for this project. The analysis only represents the conditions at the subject property at the time of the analysis and using the most current version of the US EPA air dispersion model AERMOD. The prediction and conclusions presented herein represent the best judgment of the author based on current modeling methodology and standards. CH2M HILL attests that to the best of our knowledge, the information presented in this report is accurate.

# 6 References

Havlicek, S.C., L.R. Hilpert, G. Dai and D. Pierotti. 1992. Assessment of ethylene oxide concentrations and emissions from sterilization and fumigation processes. Final report. Prepared for Research Division, California Air Resources Board, Sacramento, California (Contract No. A832-125).

Schulman L.L., D.G. Strimaitis, and J.S. Scire. 2000. "Development and Evaluation of the PRIME Plume Rise and Building Downwash Model". Journal of the Air & Waste Management Association, 50: 378-390.

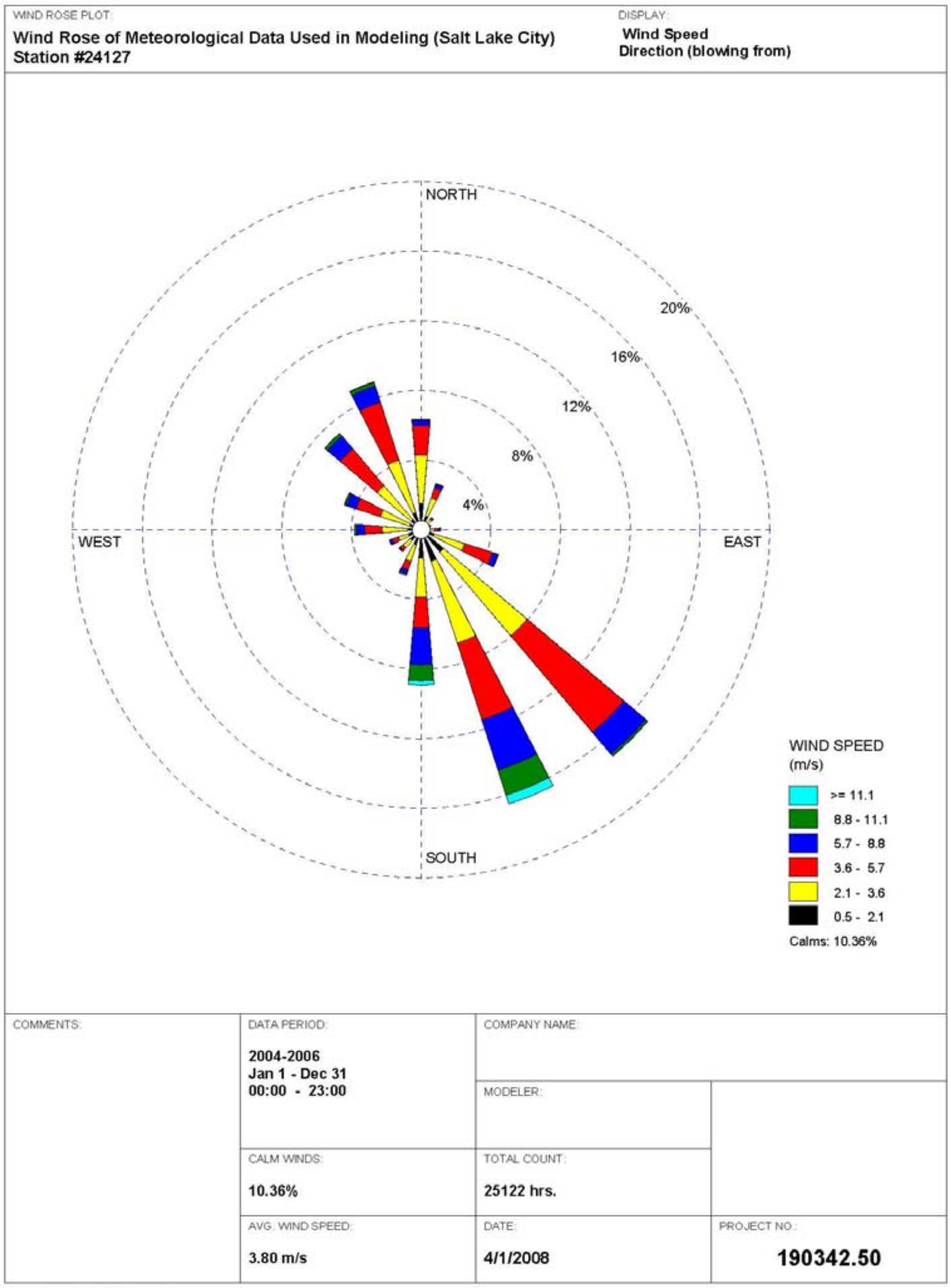
United States Environmental Protection Agency (US EPA). 1998. User's Guide for the AERMOD Meteorological Processor (AERMET), U.S. Environmental Protection Agency, Research Triangle Park, N.C.

United States Environmental Protection Agency (US EPA). 1998. User's Guide for the AMS/EPA Regulatory Model AERMOD, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

Office of Environmental Health Hazard Assessment report, Public Hearing to Consider the Adoption of a Regulatory Amendment Identifying Ethylene Oxide as a Toxic Air Contaminant, September 1987

United States Department of Health and Human Services, Agency for Toxic Substances & Disease Registry, Medical Management Guidelines for Ethylene Oxide, Updated September 24 2007

# Attachment A
# Windrose of Meteorological Data Used In Modelling

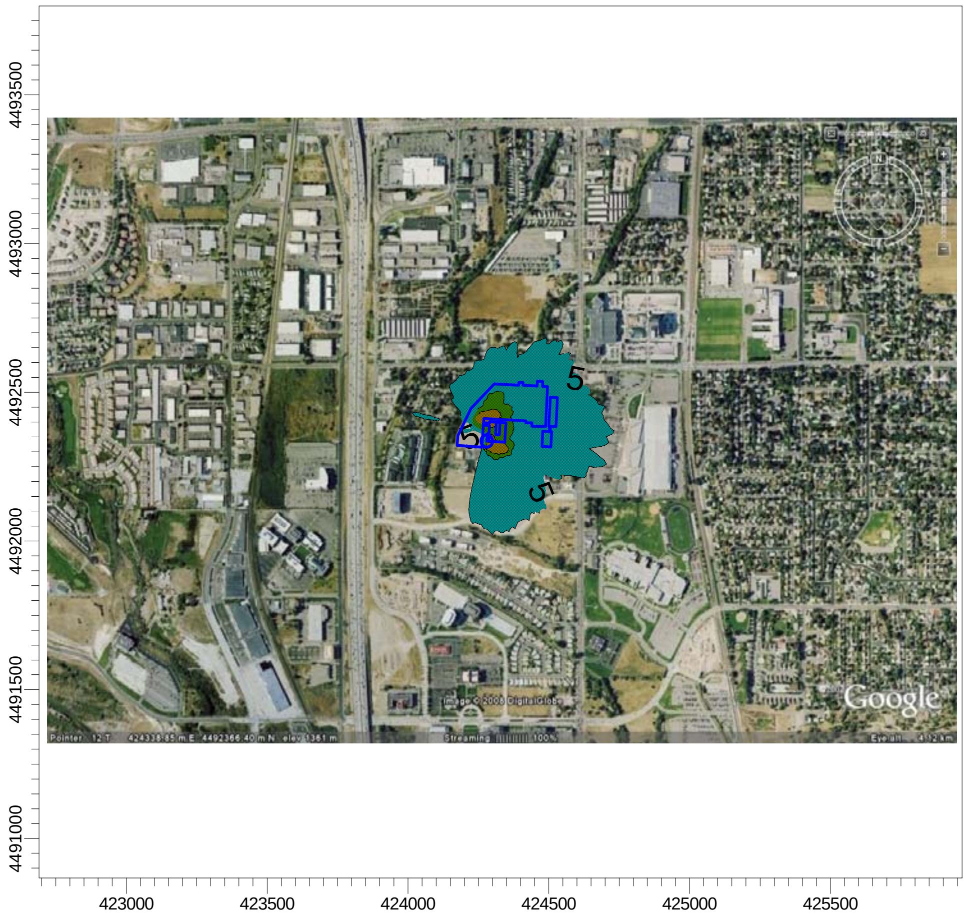


WRPLOT View - Lakes Environmental Software

# Attachment B
# Concentration Contour Plots

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 1 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP1 PPM

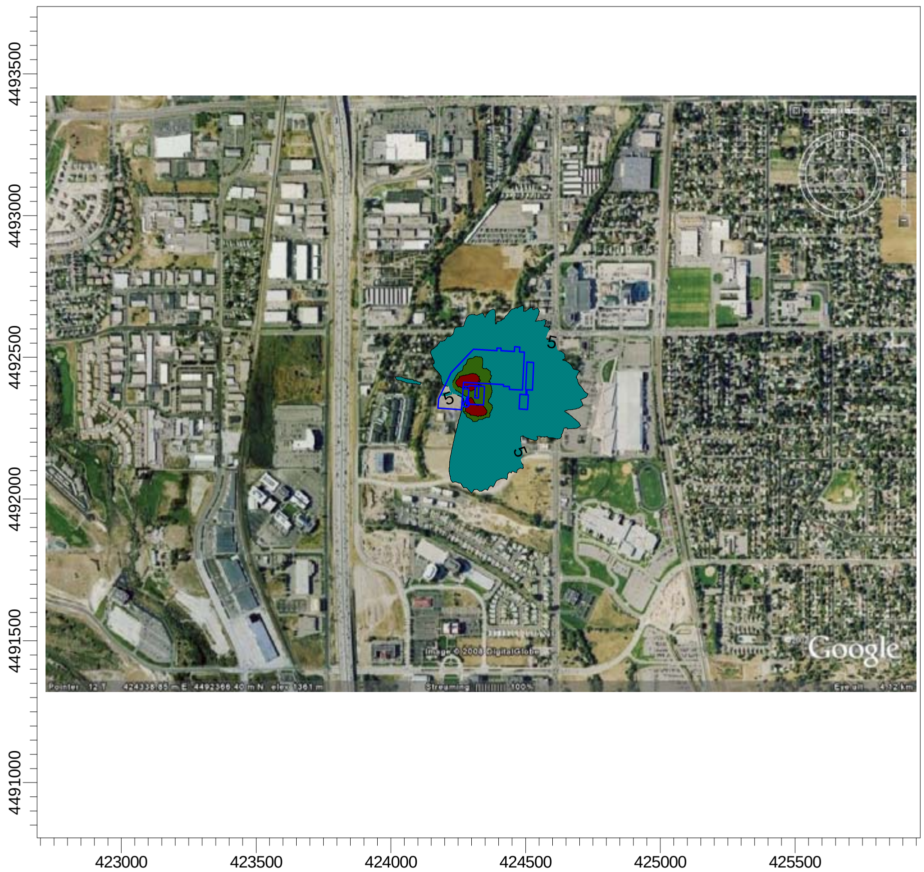
5 10 20

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA IDLH Criterion 800 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**32.45945 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

ISC-AERMOD View - Lakes Environmental Software C:\Documents and Settings\qshen\My Documents\Cshen\Project\Weyerhaeuser\BD\AERMOD3\EO1hr.isc

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 1 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**



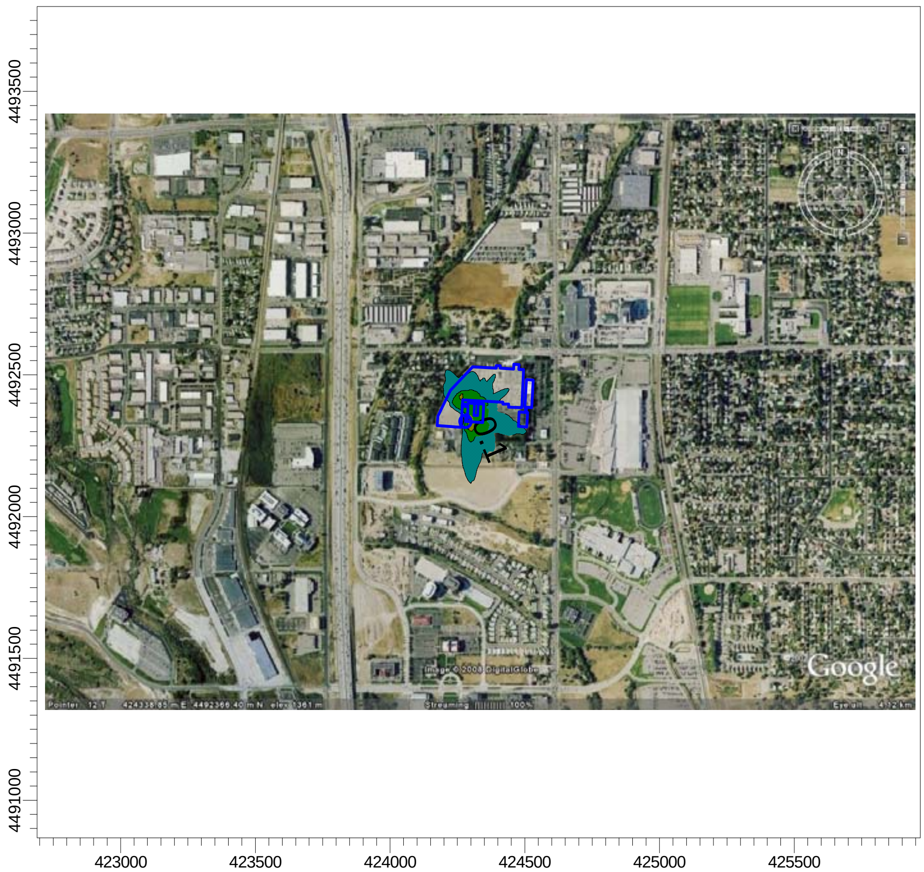

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP1 PPM

5 10 20

| | | | |
|---|---|---|---|
| COMMENTS:<br>ACGIH STEL Criterion 5 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 ▬ 0.5 km | |
| | MAX:<br>**32.45945 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 1 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**



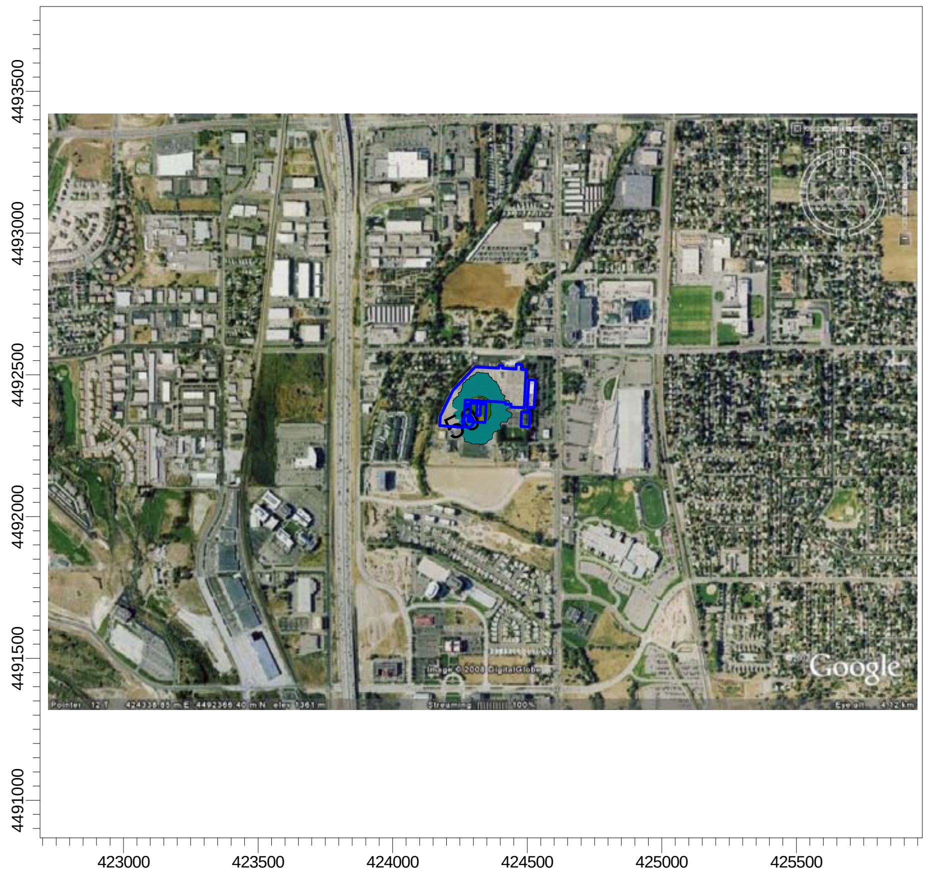

PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: SRCGP1 PPM

0.1 0.2 0.5

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA PEL Criterion 1 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**0.69668 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 2 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**



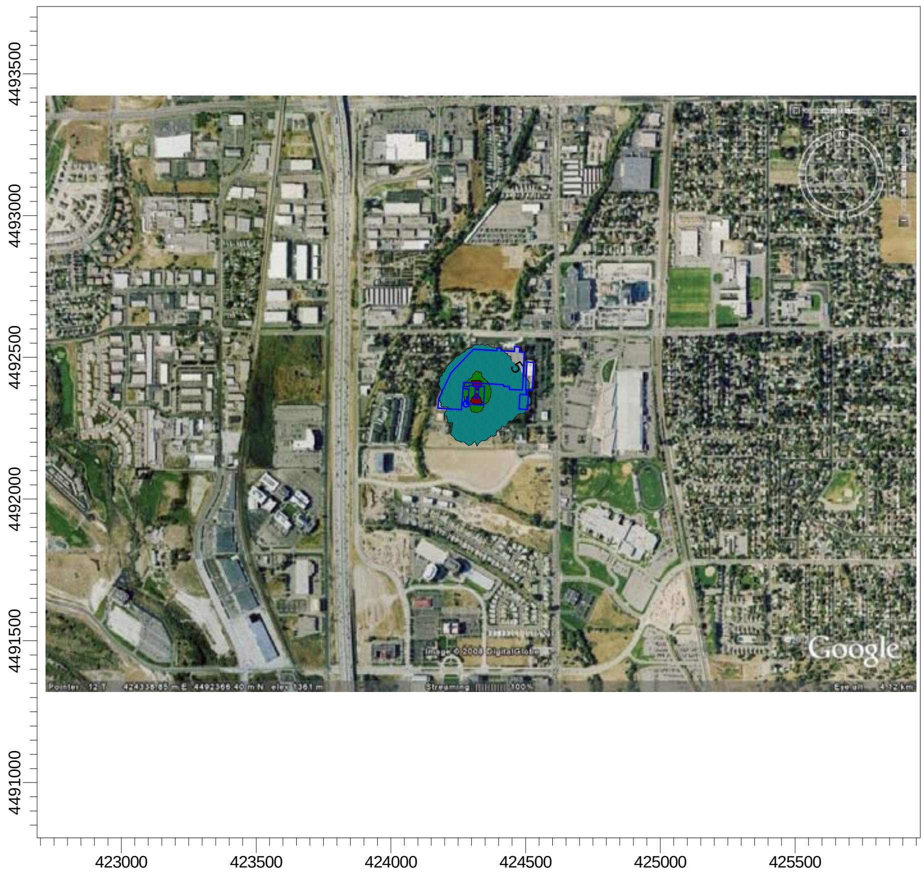

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP2 PPM

50 100 150 200

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA IDLH Criterion 800 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**233.1 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 2 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**



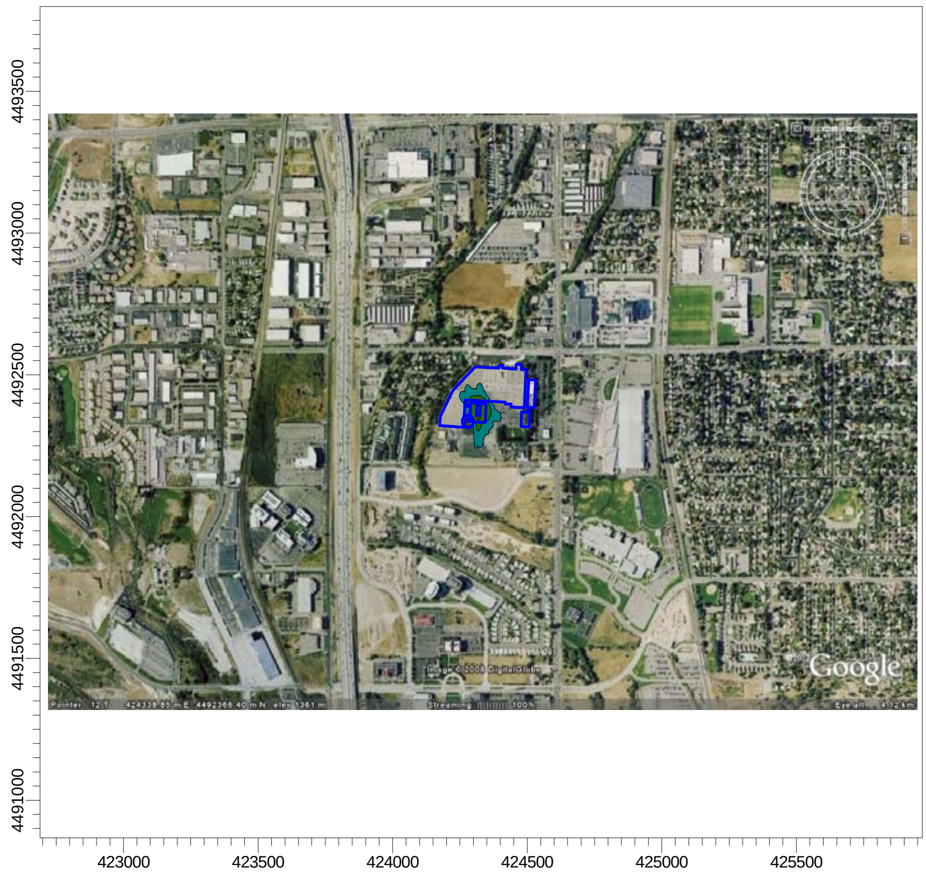

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP2 PPM

5 10 20

| COMMENTS: | SOURCES: | COMPANY NAME: | |
|---|---|---|---|
| ACGIH STEL Criterion 5 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 0 0.5 km | |
| | MAX: **31.08 PPM** | DATE: **4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 2 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**



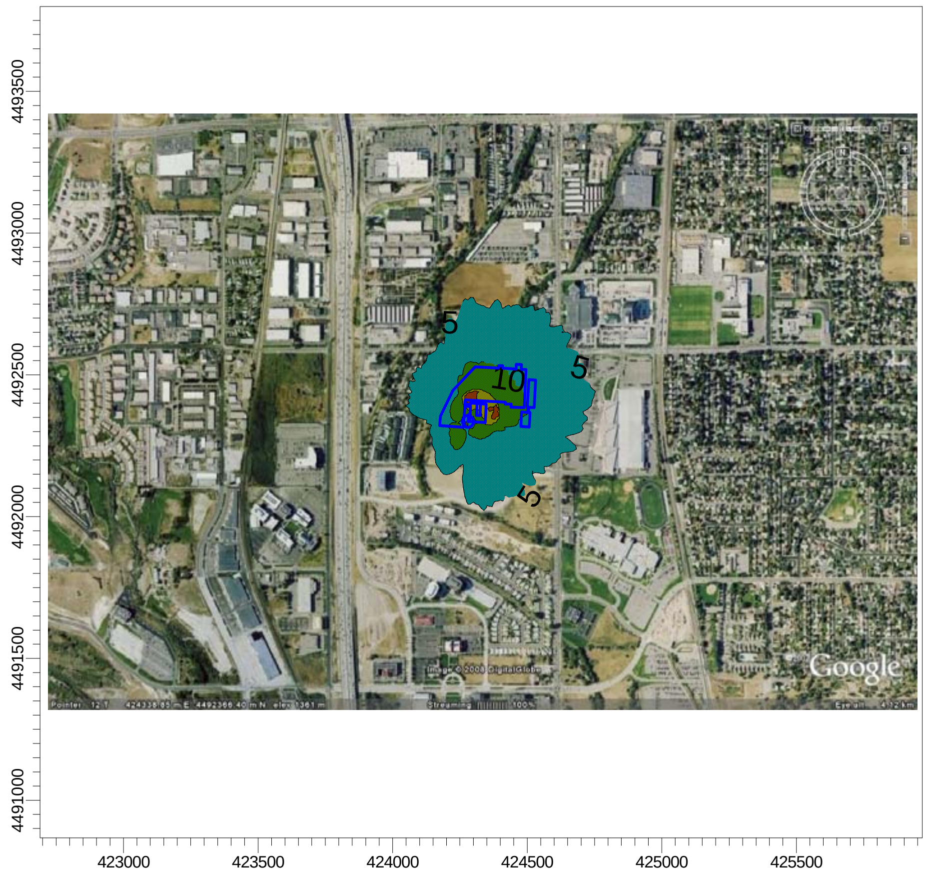

PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: SRCGP2 PPM

0.1 0.2 0.5

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA PEL Criterion 1 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 — 0.5 km | |
| | MAX:<br>**0.65764 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 3 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**



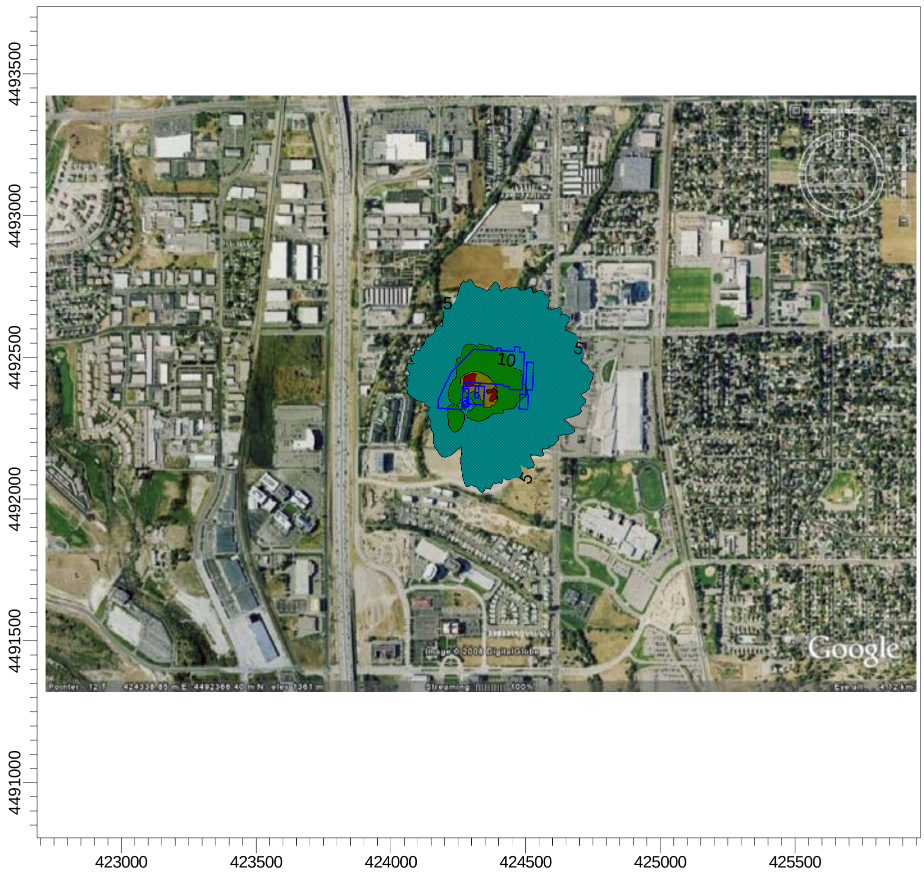

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP3 PPM

5 10 20 30

| COMMENTS: | SOURCES: | COMPANY NAME: | |
|---|---|---|---|
| OSHA IDLH Criterion 800 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 0 — 0.5 km | |
| | MAX: **41.22357 PPM** | DATE: **4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 3 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP3 PPM

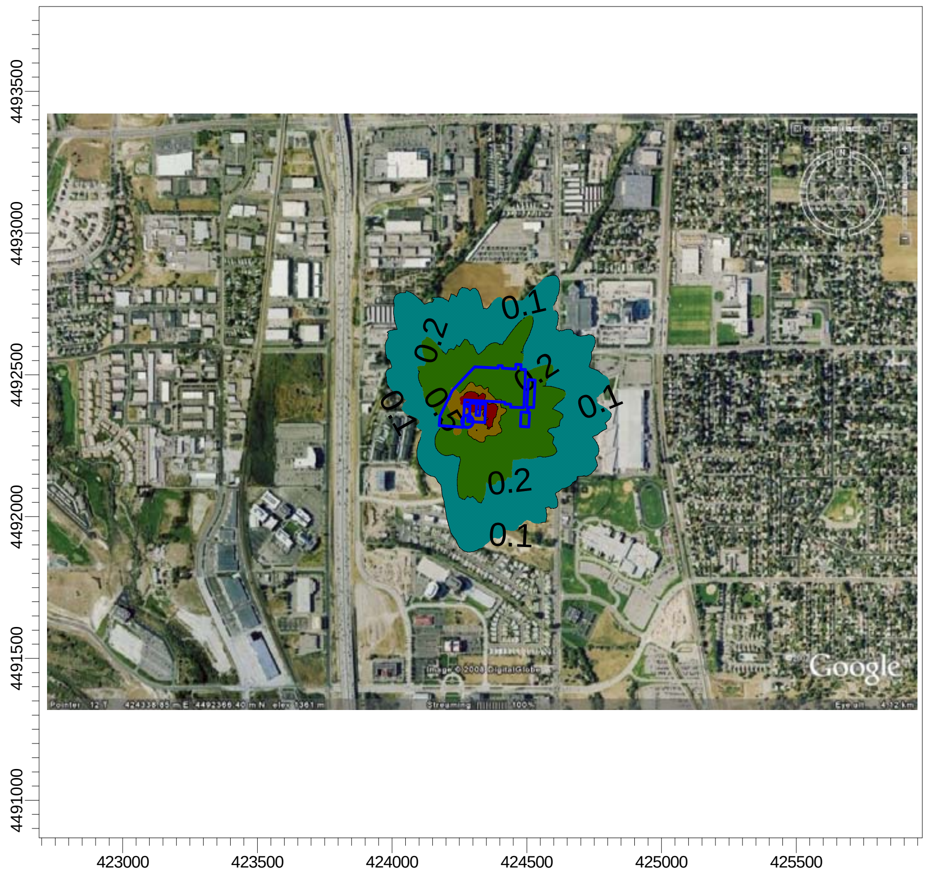
5 10 20 30

| | | | |
|---|---|---|---|
| COMMENTS: | SOURCES: | COMPANY NAME: | |
| ACGIH STEL Criterion 5 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: | | |
| | **13281** | | |
| | OUTPUT TYPE: | SCALE: 1:20,000 | |
| | **Concentration** | 0 ▬ 0.5 km | |
| | MAX: | DATE: | PROJECT NO.: |
| | **41.22357 PPM** | **4/11/2008** | |

ISC-AERMOD View - Lakes Environmental Software C:\Documents and Settings\qshen\My Documents\Cshen\Project\Weyerhaeuser\BD\AERMOD3\EO1hr.isc

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 3 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: SRCGP3

PPM

0.1 | 0.2 | 0.5 | 1.0

| COMMENTS: | SOURCES: | COMPANY NAME: | |
|---|---|---|---|
| OSHA PEL Criterion 1 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 (0 — 0.5 km) | |
| | MAX: **1.74322 PPM** | DATE: **4/11/2008** | PROJECT NO.: |

ISC-AERMOD View - Lakes Environmental Software

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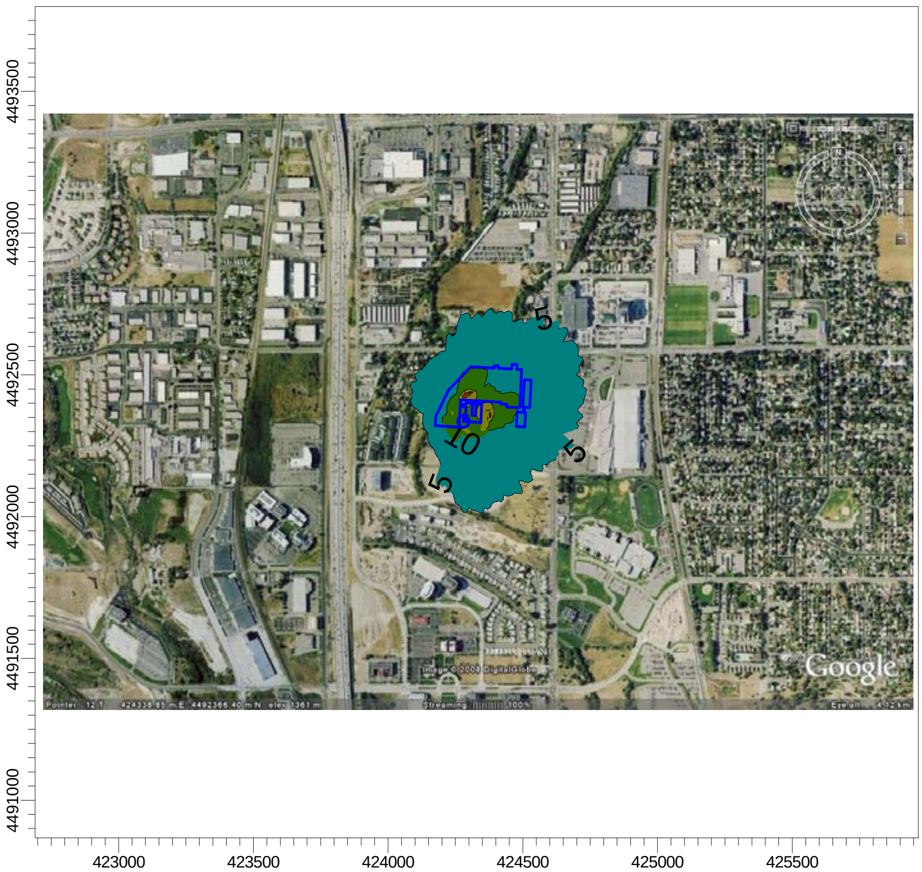
PROJECT TITLE:

**Ethylene Oxide Release - Scenario 4 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**



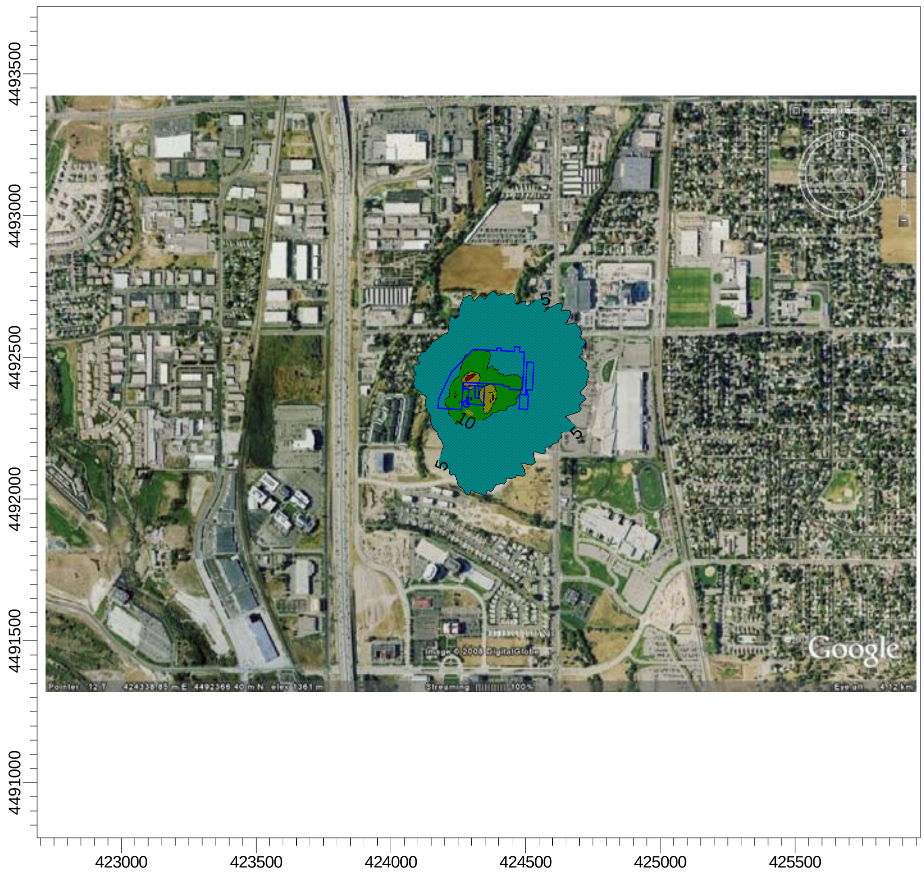

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP4 PPM

5 10 20 30

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA IDLH Criterion 800 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**34.07041 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 4 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**



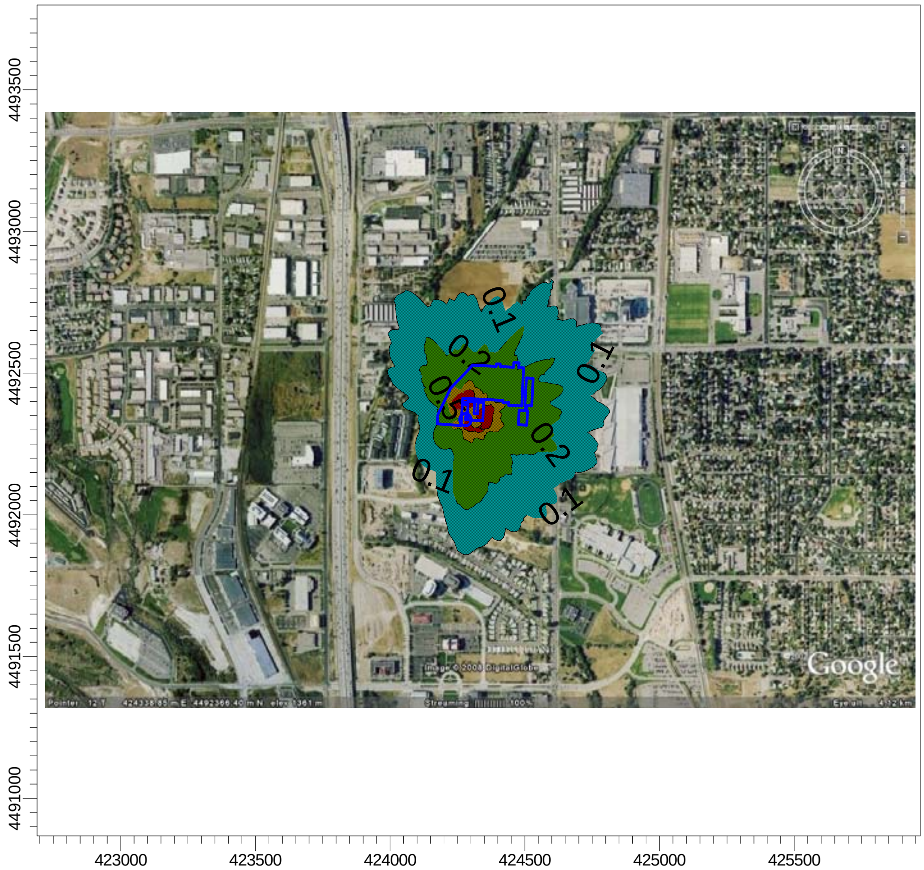

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP4 PPM

5 10 20 30

| | | | |
|---|---|---|---|
| COMMENTS:<br>ACGIH STEL Criterion 5 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**34.07041 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 4 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**



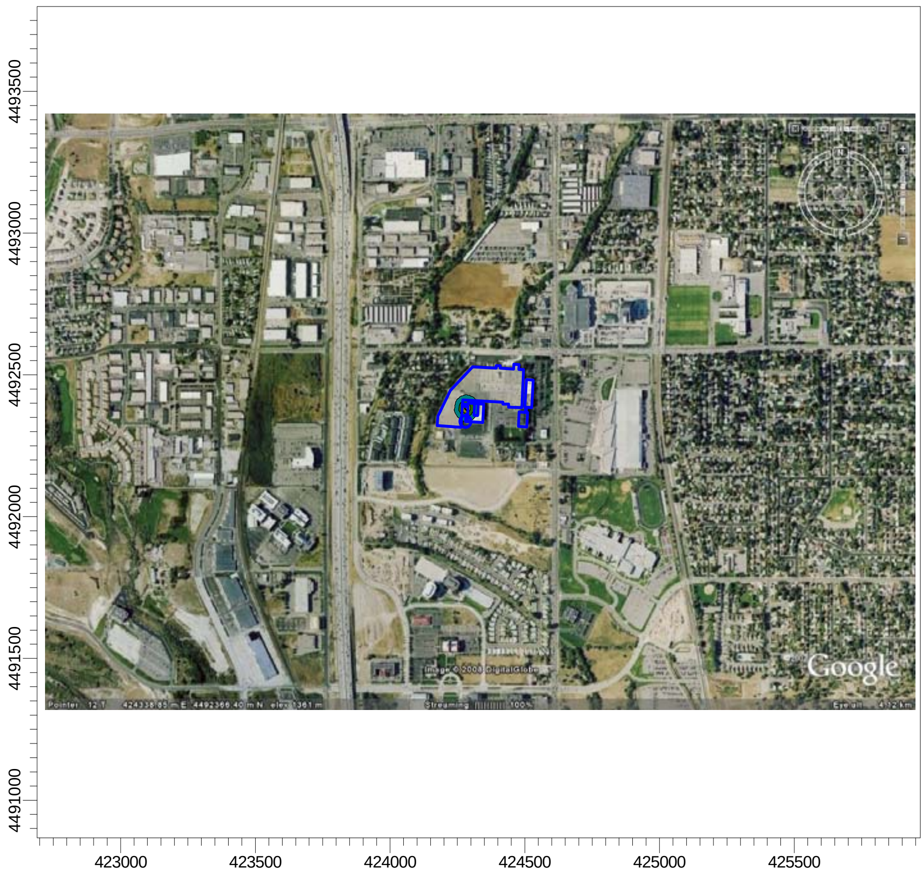

PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: SRCGP4 PPM

0.1 0.2 0.5 1.0

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA PEL Criterion 1 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 ― 0.5 km | |
| | MAX:<br>**1.72525 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 5 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP5 PPM

5 10 20

| | | | |
|---|---|---|---|
| COMMENTS: | SOURCES: | COMPANY NAME: | |
| OSHA IDLH Criterion 800 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 0 — 0.5 km | |
| | MAX: **36.95349 PPM** | DATE: **4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 5 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**

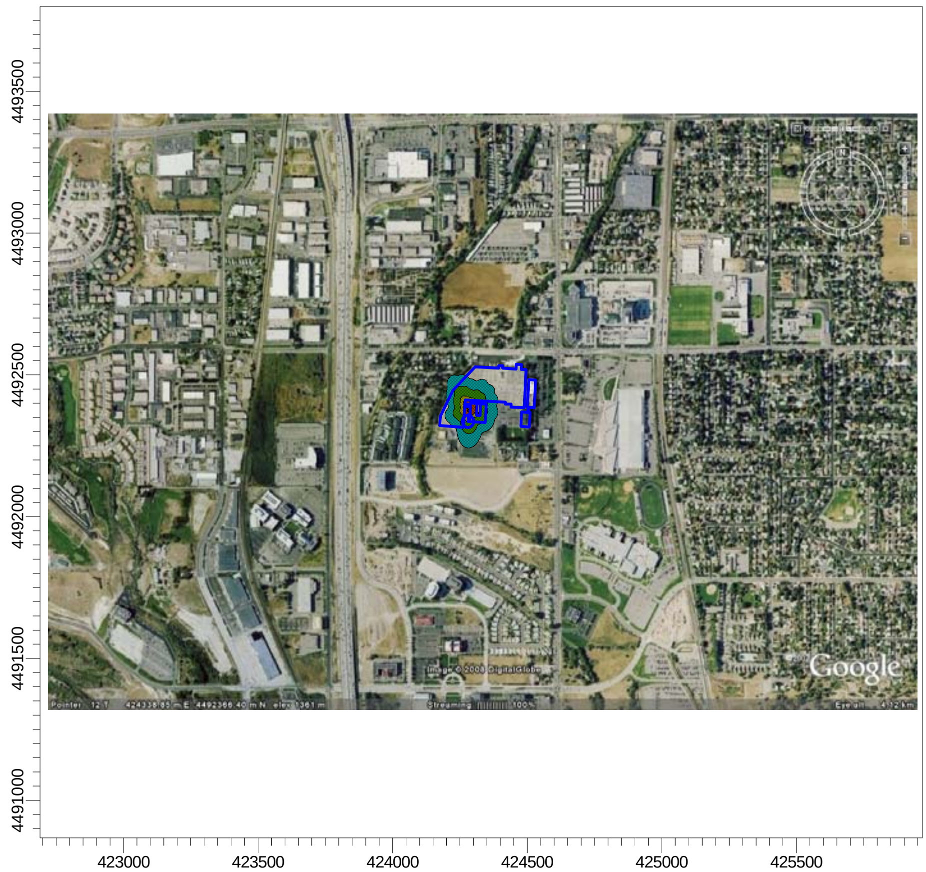

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: SRCGP5 PPM

5 15 30

| | | | |
|---|---|---|---|
| COMMENTS:<br>ACGIH STEL Criterion 5 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km | |
| | MAX:<br>**36.95349 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 5 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: SRCGP5

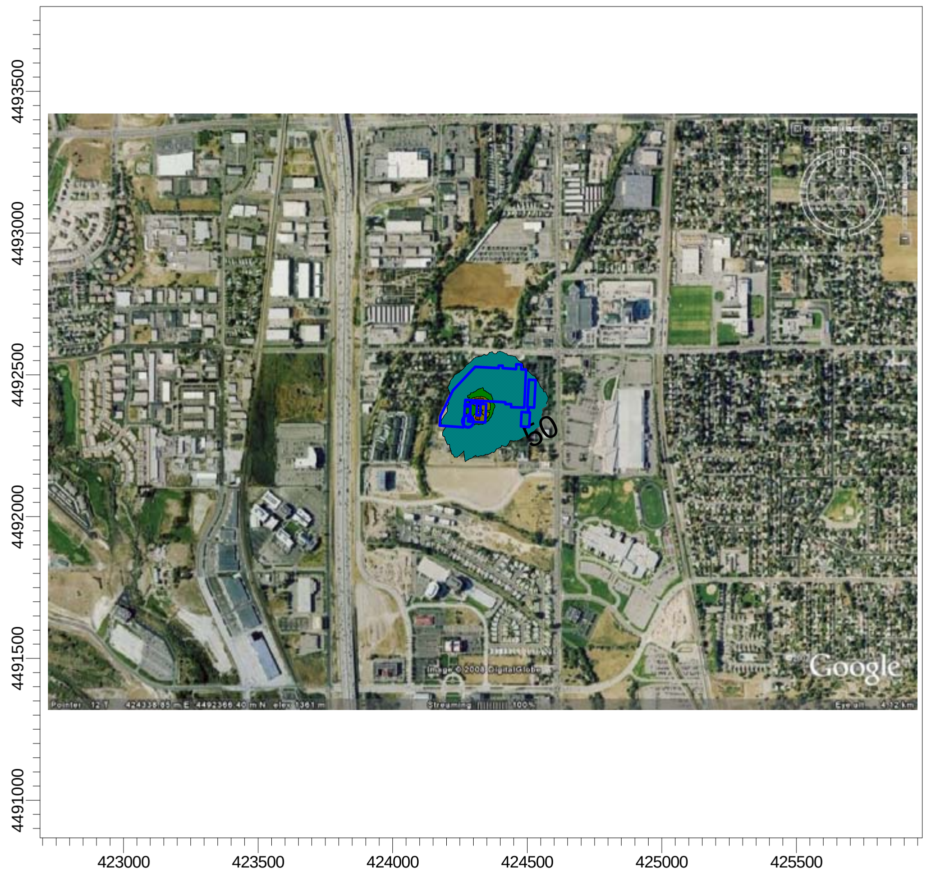
PPM

0.1 0.2 0.5 1.0 3.0

| | | |
|---|---|---|
| COMMENTS:<br>OSHA PEL Criterion 1 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** |
| | RECEPTORS:<br>**13281** | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 0.5 km |
| | MAX:<br>**4.06679 PPM** | DATE:<br>**4/11/2008** |
| | | PROJECT NO.: |

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 6 - Maximum 1-minute Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL — PPM

50 | 100 | 150 | 200

| | | | |
|---|---|---|---|
| COMMENTS:<br>OSHA IDLH Criterion 800 ppm | SOURCES:<br>**8** | COMPANY NAME:<br>**CH2M HILL** | |
| | RECEPTORS:<br>**13281** | | |
| | OUTPUT TYPE:<br>**Concentration** | SCALE: 1:20,000<br>0 — 0.5 km | |
| | MAX:<br>**260.34069 PPM** | DATE:<br>**4/11/2008** | PROJECT NO.: |

ISC-AERMOD View - Lakes Environmental Software

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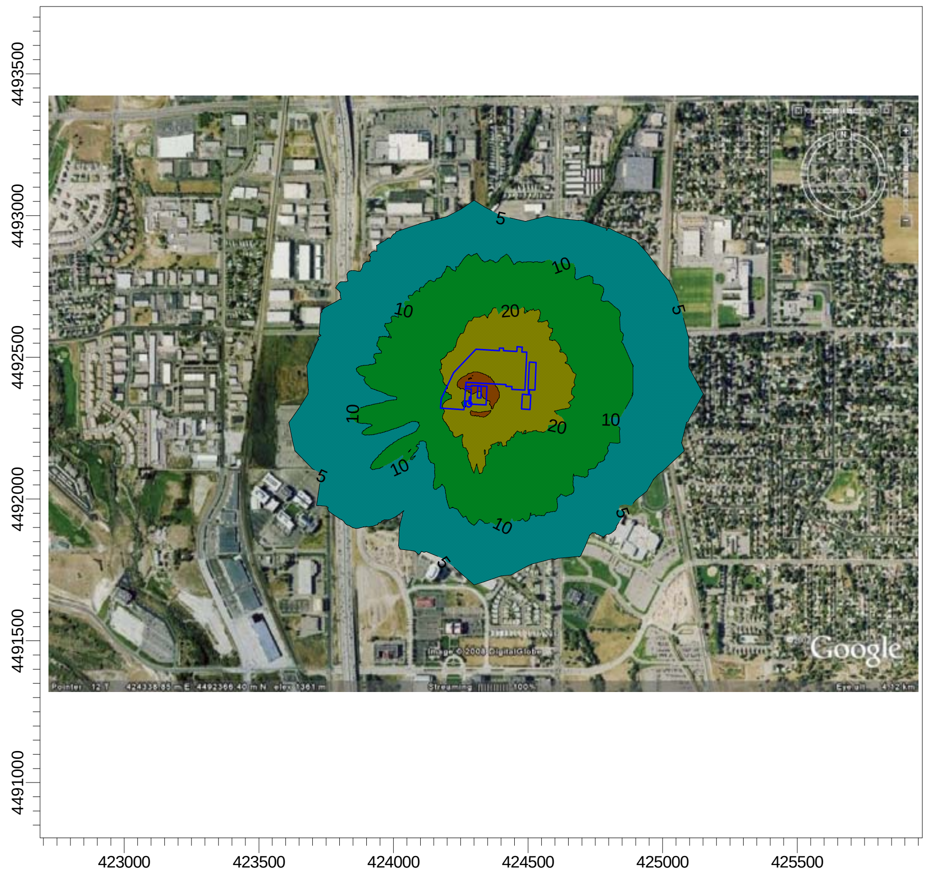
PROJECT TITLE:

**Ethylene Oxide Release - Scenario 6 - Maximum 15-minute Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

PPM

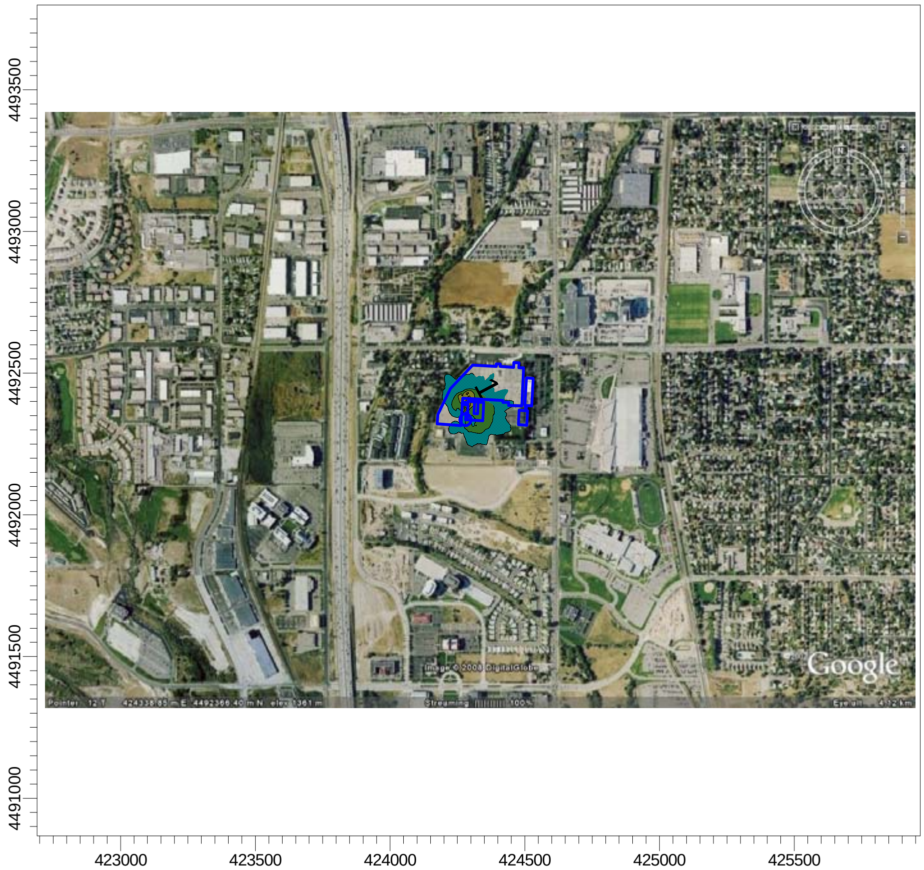
5 10 20 50 100

| COMMENTS: | SOURCES: | COMPANY NAME: | |
|---|---|---|---|
| ACGIH STEL Criterion 5 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 0 0.5 km | |
| | MAX: **104.34012 PPM** | DATE: **4/11/2008** | PROJECT NO.: |

ISC-AERMOD View - Lakes Environmental Software C:\Documents and Settings\qshen\My Documents\Cshen\Project\Weyerhaeuser\BD\AERMOD3\EO1hr.isc

PROJECT TITLE:

**Ethylene Oxide Release - Scenario 6 - Maximum 8-hour Release**
**Becton Dickenson Sandy Utah**




PLOT FILE OF HIGH 1ST HIGH 8-HR VALUES FOR SOURCE GROUP: ALL — PPM

1 — 2 — 3 — 4 — 5

| COMMENTS: | SOURCES: | COMPANY NAME: | |
|---|---|---|---|
| OSHA PEL Criterion 1 ppm | **8** | **CH2M HILL** | |
| | RECEPTORS: **13281** | | |
| | OUTPUT TYPE: **Concentration** | SCALE: 1:20,000 — 0 ▬ 0.5 km | |
| | MAX: **6.91805 PPM** | DATE: **4/11/2008** | PROJECT NO.: |